August 14, 2001

MEMORANDUM TO: Cynthia Carpenter, Chief
Generic Issues, Environmental, Financial &
Rulemaking Branch
Division of Regulatory Improvement Programs, NRR

FROM: Joseph L. Birmingham, Project Manager/**RA/**
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SUBJECT: SUMMARY OF JULY 26-27, 2001, MEETING WITH NUCLEAR ENERGY INSTITUTE AND INDUSTRY ON ECCS STRAINER BLOCKAGE IN PWRS

On July 26-27, 2001, Nuclear Regulatory Commission (NRC) staff met with representatives of the Nuclear Energy Institute (NEI), the Westinghouse Owners Group (WOG), the Babcock and Wilcox Owners Group (B&WOG), and the Combustion Engineering Owners Group (CEOG) to discuss preliminary findings of draft technical report, "GSI-191: Parametric Evaluations for Pressurized Water Reactor Recirculation Sump Performance," dated July 2001, performed by Los Alamos National Laboratories (LANL) for the NRC's Office of Nuclear Regulatory Research (RES). The study was performed in support of the NRC's Generic Safety Issue (GSI) 191 study to determine if sump failure is a plausible concern for pressurized water reactors (PWRs). The draft technical report was made publicly available prior to the meeting and is available in NRC's document management system, ADAMS, under accession number ML011860039. The meeting attendees are listed in Attachment 1. The presentation material, "Generic Safety Issue 191, Overview of Study and Overview of Results," is available from ADAMS. The sections of the presentation material and the accession numbers to obtain them from ADAMS are itemized in Attachment 2. The presentation material includes risk considerations for GSI-191 presented during the meeting. As noted at the meeting, the risk considerations material is preliminary, is still under agency review, and is subject to change.

The emergency core cooling strainer (ECCS) blockage concern arose after an event occurred at a Swedish Boiling Water Reactor (BWR) in 1992 and two events that occurred at a domestic BWR in 1993. The NRC issued Bulletin 93-02, Supplement 1, "Debris Plugging of Emergency Core Cooling Suction Strainers," requesting BWR licensees to take any immediate compensatory measures necessary to ensure the functional capability of the ECCS. The staff then performed calculations to assess the vulnerability of domestic BWRs and conducted a detailed study of a reference BWR 4 with a Mark 1 containment. The results of the staff study were issued in report NUREG/CR-6224, "Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris," which was published in October 1995. At that time, the staff did not evaluate the vulnerability of PWRs to ECCS sump blockage because of significant differences in the size and configuration of PWRs. However, following resolution of the concern for BWR ECCS systems, the staff began evaluation of the potential vulnerability of PWRs and contracted LANL to evaluate the potential for debris to cause degraded PWR recirculating sump performance.

Frank Gillespie, of the NRC's Office of Nuclear Reactor Regulation (NRR), began the meeting with an agency overview of the status of the GSI-191 issue. Mr. Gillespie emphasized that the purpose of this meeting was to present the preliminary results of the LANL study and to hear comments from industry and other stakeholders on the assumptions and calculations in the report. Mr. Gillespie pointed out that the agency was still evaluating the Generic Safety Issue and had actions to complete in that process before it could determine what regulatory actions were needed. Mr. Gillespie stated that the basis for continued PWR operation during the NRC's GSI evaluation process is contained in the April 2001 Action Plan on ECCS Suction Blockage in the NRR Director's Quarterly Status Report. An excerpt of those justifications is included in this memorandum as Attachment 3. Mr. Gillespie encouraged the participants to ask questions, to point out weaknesses in study assumptions, and to discuss how the generic evaluation might apply differently to specific PWRs. Mr. Gillespie indicated that, although the agency was not yet ready to begin regulatory actions, he would be available to hear questions from all stakeholders at the end of the meeting.

Mr. Michael Marshall, of the NRC's Office of Nuclear Regulatory Research (RES), then gave an overview of the study and described the purpose of the GSI-191study. The purpose of the study was to determine if debris accumulation on sump screens will cause a loss of net positive suction head (NPSH) margin following a loss-of-coolant accident (LOCA) and to determine if regulatory action is needed. The preliminary findings of the study are that some PWRs could lose NPSH margin, based on the parametric calculations assuming a large-break LOCA, medium LOCA, or small-break LOCA. The parametric calculations are not suitable for conclusions about a specific PWR but are suitable for drawing generic conclusions.

Mr. Marshall stated that the data sources for the study were the industry survey conducted by NEI, the responses to Generic Letter 97-04: "Assurance of Sufficient Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Pumps," detailed data from two volunteer plants, Individual Plant Examination reports, emergency operating procedures, updated Final Safety Analysis Reports (UFSARs), and MELCOR and RELAP calculations. Testing done for the study included debris generation and debris transport. Calculations that resulted from the study are the GSI-191 Parametric Evaluation and a "generic" risk estimate. Mr. Marshall indicated that it was important to note that the definition for sump failure used for the study was loss of NPSH margin which does not necessarily mean that the ECCS pumps would be unable to continue providing water to the core.

Mr. Marshall described the documentation resulting from the study which included technical letter reports for ice condenser containments and for large dry containments phenomena identification and ranking tables, and the GSI-191 Parametric Evaluation. Also, information would be available in NUREG/CRs (expected CY 2002) on the GSI-191 Parametric Evaluation, GSI-191 Risk Estimates, GSI-191 Containment and Sump Survey, GSI-191 Debris Generation and Debris Transport Tests, and GSI-191 Review of Sump Blockage Tests and Analyses. In response to a question, Mr. Marshall indicated that the information from the technical letter reports was included in the meeting presentation material. LANL personnel then presented the preliminary results of the parametric evaluation.

Dr. D.V. Rao, of LANL, began the presentation by giving a description of the background and qualifications of those persons who worked on the study. Significant among these was the experience gained during the development of the BWR parametric evaluation. Dr. Rao discussed what was meant by "favorable" and "unfavorable" assumptions, and demonstrated how the calculations were performed utilizing parametric case 17 as an example. Dr. Rao

described typical sump screen installations and explained the difference between fully and partially submerged sump screens indicating that fully submerged screens would be expected to benefit from the additional head caused by the depth of water in the containment whereas the partially submerged would not.

Mr. Scott Ashbaugh, of LANL, discussed how information from the industry sump and containment survey was collected, supplemented by other sources, and used in the parametric evaluation. He indicated that a wealth of information was obtained from the industry survey, however, the survey information alone was not sufficient to perform a detailed assessment. Hence the information was supplemented from other valid sources such as technical specifications and UFSARs.

Dr. Rao then continued with the technical discussion of the approach. He described how NPSH loss and threshold debris values were determined and presented charts and diagrams illustrating these values. Industry asked the purpose of a chart showing expected head loss greater than 50 feet which was well over design margin. Dr. Rao explained that it demonstrated the very real potential for high head losses from the types of fiber and debris in the example.

Dr. Bruce Letellier, of LANL, gave a description of the types of debris sources and the relative importance of the debris. The debris could be divided into two main types, fibrous and particulate. These two types are subdivided further in the study but for purposes of the presentation were sufficient. The fibrous debris is derived mainly from insulation on piping and plant structures. The particulate debris is derived from dust in the containment, paint or coating material knocked loose by the high-pressure, high-temperature coolant escaping from the break, and various nonfibrous insulation impinged by the jet of two-stage coolant. Also, zinc and aluminum particulates would also be expected to develop from materials inside the containment. Reflective metallic insulation (RMI) was also discussed, however, RMI was found to be the least transportable debris type. Dr. Letellier described the filtration effect of combined fiber and particulate debris beds. Specifically, the fibrous insulation accumulating on the sump screen creates a fine filter which then traps the particulate debris creating a surface that has a high resistance to the flow of water, and results in a very high head loss across the sump screen.

Dr. Letellier gave a discussion on the generation of debris. He described the zone of influence (ZOI), (i.e., the zone in which coolant impinges on containment surfaces) and the size, amounts and types of debris that could theoretically be generated by different sizes of pipe breaks. He presented charts showing potential particulate sources of debris such as the corrosion and precipitation of zinc and aluminum under various pH levels and the potential dust loading based on estimated containment horizontal surface areas. Dr. Letellier discussed how distance from the break and other factors affected the amount of insulation debris generated by a LOCA. He presented a chart showing the relative amounts of insulation debris generated for typical types of insulation used in nuclear power plants. Dr. Letellier discussed how information used in the parametric study on BWRs was applicable or could be adapted for PWRs and also discussed the differences. One major difference between BWRs and PWRs is the portion of the debris that is produced from calcium-silicate (cal-sil) insulation. Cal-sil in combination with fibrous insulation accumulated on sump screens forms a barrier significantly more impervious than the other types of debris, and results in substantially higher head losses.

Dr. Letellier also described a computer code developed to evaluate debris generation and used in the study. The code is called **C**ontainment **A**ccident **S**equence **In**sulation **O**utcome

Verification **A**nalysis or **CASINOVA** and among other abilities can accept spatial pipe and equipment data cross referenced by reactor system, insulation type, and pipe diameter. The computer code has many other features and is described in the report and presentation material. The code allowed the study to analyze various configurations based on pipe break size, containment type, debris sources, and debris volumes.

Dr. Rao, Dr. Letellier, and Dr. Arup Maji, of the University of New Mexico, discussed debris transport and accumulation. This presentation provided a discussion of the analyses and testing done in support of the generic transport fractions assumed in this study. Steps in this process were:

1. Provide minimum threshold values of debris necessary to cause sump screen blockage.

2. Provide "Generic" and "Case-Extrapolated" values for the quantity of fibrous debris in the ZOI.

The presenters emphasized that the focus was to obtain "plausible" transport fractions of fibrous debris rather than "best-estimate" values. The debris of interest for this discussion was fibrous debris (large clumps and fine fiber).

Linear flume testing demonstrated that large fibrous debris (clumps) tend to float for several minutes and transport readily by even small fluid velocities. After sinking, high velocities are needed to move the large fibrous clumps. Small shreds of fiber are transported by very low fluid velocities (i.e., 0.1 foot/second) and are kept in suspension by low levels of turbulence. Because of these differences, and to simplify the parametric analyses, the analyses concentrated on the fine fiber transport. The presenters described the methodology used to determine the factors affecting debris transport. The factors were ZOI inventory, debris size, blowdown, washdown, and water transport. The factors were described in detail as to how each would affect sump screen blockage. Depending on the factors assumed, sufficient debris was considered to be transported for many of the parametric cases to meet the minimum threshold quantity needed to cause "sump failure"[1].

Dr. Maji presented information on the testing performed to understand the debris transport. Some of the testing consisted of a sump in a tank configured to represent the layout of a containment while simulating various pipe break sizes and locations. Other testing was performed using a flume configuration and typical sump screen material to obtain debris transport and accumulation characteristics. Computer simulations were also used. A video of the tank testing showed the different ways the fibrous debris was transported depending on the location and size of the simulated pipe break. More details on the testing are contained in the presentation material itemized in Attachment 2.

The presenters discussed how particulate debris would be expected to be generated by a LOCA, transported by water flow and accumulated on fibrous debris accumulated at the sump screen. The testing indicated that, once a layer of fibrous debris accumulated on the sump screen, the particulate debris was entrapped by the fibrous debris. The resulting debris bed created a significant head loss and reduced the water flow through the sump screen. A layer of

[1]Utilizing the definition of "sump failure" defined in the GSI-191 Parametric Evaluation Report.

fibrous material of about 1/8 inch, combined with the particulate debris, was considered sufficient to cause significant reductions in NPSH to the ECCS pumps.

At this point, Arthur Buslik, of RES, presented an assessment of the risk considerations associated with GSI-191. The assessment is preliminary and is still under agency review but was presented at the meeting for purposes of discussion. In general, the assessment calculated the potential decrease in core damage frequency and the cost-benefits of fixing the sump screen blockage issue. The methodology and assumptions used to make the assessment were discussed. The accession number for the risk assessment is itemized on Attachment 2.

At this time, the NRC answered questions from the participants about the presentation. Some questions asked for clarification of points in the study and one licensee asked questions about the variability of the assumptions used in the study. The presenters agreed that there was some variability involved in the assumptions but that the assumptions were in general "favorable". However, whether an assumption was favorable depended in part on the specific facility. NEI asked what additional research was planned and the staff responded that the majority of the research was finished but some additional research was planned on the effect of calcium silicate on sump screen blockage.

The parametric study and the presentation material indicate that significant quantities of fibrous and particulate debris will be generated during various size LOCAs. Further, on a generic basis, a sufficient fraction of fibrous and particulate debris may be transported to the sump screen and cause sump screen blockage. Factors that affect the generation and transport of debris with the potential for sump screen blockage include, type and amount of fiber insulation installed, type and amount of particulate debris generated, configuration of walls and equipment within containment, piping configuration, potential locations of pipe breaks, size and type of sump screens, configuration and location of ECCS sumps, activation of containment spray, additional sources of emergency coolant, and emergency operating procedures. Other factors also exist. The parametric study and other work performed as part of GSI-191 will provide a basis for agency evaluation of the need for regulatory action. The agency is interested in the input from external stakeholders as to the validity of the study and the assumptions.

At the end of the meeting, Michael Marshall summarized the meeting and restated comments made by the licensees and NEI during the meeting. The comments are included in this memorandum as Attachment 4. Frank Gillespie, offered to hear regulatory comments from the participants and restated that the agency had not yet begun the process for determining an appropriate regulatory response. NEI and the other participants stated that they would like the opportunity to submit more detailed questions about the report and agreed to send the comments to the staff in about a week.

Having completed discussion of the agenda items, the meeting was adjourned.

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*** See previous concurrence**
DOCUMENT: G:\RGEB\JLB\MSUM-NEI PWR Blockage 07/26-27/01.WPD

OFFICE	DRIP/RGEB	DSSA/SPLB	RES/ERAB	DRIP/RGEB
NAME	JBirmingham	RElliott	MMarshall	SWest
DATE	08/15/01	08/13/01	08/13/01	08/14/01

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Attendees for July 26-27, 2001, Meeting
PWR ECCS Blockage, GSI-191

NAME	ORGANIZATION
K. Cozens	NEI
A. Marion	NEI
J. Gisclon	EPRI
S. Winter	Nuclear Mgt. Co./Consumers
J. Ressler	OPPD
J. Brown	APS
M. Dingler	WCNOC/WOG
G. Darden	Dominion
B. Bryan	TVA
T. Andreychek	Westinghouse
R. Oakley	Duke Energy
C. Hutchins	Westinghouse
G. Dolderer	FPL/NUCC
B. Lubin	Westinghouse
G. Quituriano	Pacific Gas & Electric
G. Hart	Performance Contracting Group
G. Zigler	ITS Corp.
C. Fago	Duke Engineering Services
C. Harrington	TXU Electric
Joan Cho	Stone & Webster
F. Elia	Stone & Webster
S. Jones	Self
M. Mayfield	NRC/RES/DET
J. Boardman	NRC/RES/DET
D. Dorman	NRC/RES/DET/ERAB
M. Marshall	NRC/RES/DET/ERAB
K. Karwoski	NRC/RES/DET/ERAB
A. Buslik	NRC/RES/DET/PRAB
J. Ireland	Los Alamos National Laboratories (LANL)
S. Ashbaugh	LANL
D. V. Rao	LANL
B. Letellier	LANL
A. Maji	Univ. of New Mexico
G. Hubbard	NRC/NRR/SPLB
J. Hannon	NRC/NRR/SPLB
R. Elliott	NRC/NRR/SPLB
R. Architzel	NRC/NRR/SPLB
J. Lamb	NRC/NRR/DLPM
J. Birmingham	NRC/NRR/DRIP/RGEB

Accession Numbers for Presentation Material on GSI 191
for July 26-27, 2001 Public Meeting On PWR ECCS Blockage

Presentation Section	ADAMS Accession Number
Overview of Study and Results	ML012130375
Parametric Evaluation and Results	ML012130341
Analysis of Postulated Accidents	ML012130162
Review of GSI-191 Industry Survey	ML012130312
Headloss and Threshold Debris Volumes	ML012130321
Debris Generation and Source Terms	ML012130303
Debris Transport and Accumulation	ML012130333
Debris Buildup and Headloss Part 1	ML012130386
Debris Buildup and Headloss Part 2	ML012130347
Debris Buildup and Headloss Part 3	ML012130394
Risk Considerations Associated w/GSI-191	ML012130353

Justification for Continued Operation from
April 2001, NRR Director's Quarterly Status Report

Regulatory Assessment: Title 10, Section 50.46 of the *Code of Federal Regulations* (10 CFR 50.46) requires that licensees design their ECCS systems to meet five criteria, one of which is to provide the capability for long-term cooling. Following a successful system initiation, the ECCS shall be able to provide cooling for a sufficient duration that the core temperature is maintained at an acceptably low value. In addition, the ECCS shall be able to continue decay heat removal for the extended period of time required by the long-lived radioactivity remaining in the core. The ECCS is designed to meet this criterion, assuming the worst single failure.

However, for BWRs, experience gained from operating events and detailed analyses (including a detailed risk assessment) demonstrated that excessive buildup of debris from thermal insulation, corrosion products, and other particulates on ECCS pump strainers could occur during a LOCA. This created the potential for a common-cause failure of the ECCS, which could prevent the ECCS from providing long-term cooling following a LOCA. This led to the issuance of NRCB 96-03, and the subsequent installation of new larger strainers by BWR licensees.

The staff believes that there is sufficient new information and concerns raised relative to the potential for debris clogging in PWRs that part of this action plan has been prepared to address PWR sump blockage concerns. However, it is not clear whether a significant threat to PWR ECCS operation exists. The staff believes that continued operation of PWRs is justified because of PWR design features which would tend to prevent blockage of the ECCS sumps during a LOCA. These features would tend to be effective for insulation and coating debris. For instance, the containments in PWRs tend to be very compartmentalized making the transport of debris to the sump screens difficult. In addition, PWRs typically do not need to switchover to recirculation from the sump during a LOCA until 20-30 minutes after the accident initiation allowing time for much of the debris to settle in other places within the containment. Coating debris, in particular, would have plenty of time to settle. Clearly, the results of the staff's research program are needed before a final conclusion regarding the potential to clog the ECCS sump can be reached. In addition to these design considerations, the staff considers continued operation of PWRs to be justified because the probability of the initiating event (i.e., large break LOCA) is extremely low. More probable (although still low probability) LOCAs (small, intermediate) will require less ECCS flow, take more time to use up the water inventory in the refueling water storage tank (RWST), and in some cases may not even require the use of recirculation from the ECCS sump because the flow through the break would be small enough that the operator will have sufficient time to safely shut the plant down. In addition, all PWRs have received approval by the staff for leak-before-break (LBB) credit on their largest RCS primary coolant piping. While LBB is not acceptable for demonstrating compliance with 10 CFR 50.46, it does demonstrate that LBB-qualified piping is of sufficient toughness that it will most likely leak (even under safe shutdown earthquake conditions) rather than rupture. This, in turn, would allow operators adequate opportunity to shut the plant down safely (although debris generation and transport for an LBB size through-wall flow will still be investigated). Additionally, the staff notes that there are sources of margin in PWR designs which may not be credited in the licensing basis for each plant. For instance, NPSH analyses for most PWRs do not credit containment overpressure (which would likely be present during a LOCA). Any containment pressure greater than assumed in the NPSH analysis provides additional margin for ECCS operability during an accident. Another example of margin would be that it has been shown, in many cases, that ECCS pumps would be able to continue operating for some period

of time under cavitation conditions. Some licensees have vendor data demonstrating this. Design margins such as these examples may prevent complete loss of ECCS recirculation flow or increase the time available for operator action (e.g., refilling the RWST) prior to loss of flow. GL 97-04 is a review of NPSH calculations. No specific generic concerns were identified in the review of licensee responses.

The Probabilistic Safety Assessment Branch of NRR recently completed a preliminary assessment of the risk associated with the potential clogging of the ECCS sump in PWRs during a LOCA. In a memo from Richard J. Barrett to John N. Hannon dated March 26, 1999, it was concluded that "(d)ue to the unavailability of probabilistic models for debris-induced loss of ECCS NPSH and the plant-specific nature of the sump screen clogging issue, the scope of this risk assessment was limited to assessing the frequency of accident sequences requiring ECCS recirculation to prevent core damage for an average PWR plant. Because the probability and timing of sump screen clogging depends on LOCA size and location, among other parameters, an effort was made to present the results, for each LOCA category, separately.

The following major conclusions were reached by performing this preliminary risk assessment.

1. Results presented in this analysis strongly justify research to re-evaluate the potential for clogging of PWR sump screens by taking into account new information, thus enabling more realistic evaluation and management of associated risks.

2. Continued operation of PWRs is justified because, based on available current information, there is no evidence that the risk associated with the sump clogging issue is high enough to compromise public health and safety."

These conclusions clearly support this action plan as outlined herein.

NEI and PWROGs Comments During July 26-27, 2001 Public Meeting

1. Expected NPSH margin not licensing NPSH margin should have been used in GSI-191 parametric evaluation.

2. The methodology used in the GSI-191 parametric evaluation does not provide any insight into when sump failure would occur.

3. The basis for assuming uniform accumulation of debris is unclear.

4. The flowrate for non-Westinghouse PWRs used in the GSI-191 parametric evaluation appears to be to high.

5. The GSI-191 program did not include any head loss tests to benchmark the NUREG/CR head loss correlation against the type of debris assumed in the GSI-191 parametric evaluation.

6. Since the LLOCAs assumed in the GSI-191 parametric evaluation ranged from 6 inches up, it seems inappropriate to use the 95 percentile debris generation value in the estimate of debris on sump screen.

7. It was unclear from report and presentation if breaks were postulated in only high energy lines inside the crane wall. It seems inappropriate to include non-high energy piping and piping outside of the crane wall in the parametric evaluation.

8. The effectiveness of trash racks in reducing the amount of debris that could reach the sump screen was neglected.

9. It is unclear how distance debris travels in test facilities translates to distance debris travels in actual containment.

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